

The relationship between frontal brain asymmetry and exercise addiction

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Gapin, J.I., Etnier, J.L., & Tucker, D. (2009). The relationship between frontal brain asymmetry and exercise addiction. *Journal of Psychophysiology*, 23(3), 135-142.

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Abstract:

Previous research on the causes of exercise addiction has focused primarily on the relationships among personality traits, social influences, and disordered eating (Bamber, Cockerill, & Carroll, 2000; Beals, 2004). Few studies, however, have examined the psychophysiological nature of exercise addiction. In a related area of research in which brain activity has been related to affect and mood, results show that frontal asymmetry, as measured by electroencephalogram (EEG), is associated with negative emotions. More specifically, greater activity at right frontal electrode sites is found among individuals suffering from negative affect and depression. Because a defining feature of exercise addiction is the use of exercise to control negative mood states, it is expected that those with exercise addiction exhibit different frontal activity. This study explores the hypothesized relationship between exercise addiction and the level of baseline frontal activity asymmetry, as measured by EEG. Regularly active women ($n = 28$, M age = 32.43, $SD = 10.89$) were recruited to participate in the study. Exercise addiction status was determined by the Exercise Addiction Inventory (EAI) (Terry, Szabo, & Griffiths, 2004). After completing the EAI, each participant took part in an EEG session consisting of eight 1-min resting trials, four with eyes open, and four with eyes closed, presented in counterbalanced order. Electrodes were applied to the left and right frontal sites (F3 and F4). A regression analysis, predicting exercise addiction from frontal asymmetry, was significant, $F(1, 27) = 6.4$, $p < .05$, and indicated that greater relative left frontal activity with higher exercise addiction scores. There may be a link between frontal asymmetry, as an indicator of negative emotions, and exercise addiction in women.

Keywords: exercise addiction | asymmetrical frontal cortical activity | EEG | EEG asymmetry

Article:

Introduction

The psychological benefits of habitual exercise are well documented with numerous studies having demonstrated that regular exercise leads to enhanced mood and overall psychological well-being (e.g., Blair, 1995; Ekkekakis, Hall, Van Landuyt, & Petruzzello, 2000; Landers & Arent, 2001). For some individuals, however, habitual exercise can become a maladaptive behavior and may contribute to the development of the syndrome of *exercise addiction*. Addiction has been defined as “any compulsive activity or involvement which decreases a person’s ability to deal with other aspects of his life to the point where that activity or involvement comprises the dominant source of emotional reinforcement and identity for the person” (Peele, 1985, p. 103). There is evidence that the concept of addiction can be extended to exercise as well, primarily because the inability to engage in exercise can result in withdrawal symptoms such as depression, anxiety, irritability, and anger (Sachs & Pargman, 1979; Sazbo, 1998). Exercise addicts exercise compulsively despite illness, injury, or personal commitment, and the activity is not beneficial to their physical or psychological health (Iannos & Tiggeman, 1997). Exercise participation influences and controls every facet of their lives. While data on the prevalence of exercise addiction are sparse, it is speculated to affect approximately 1–3% of the population (Terry et al., 2004). Although various terms are used to describe this phenomenon (e.g., excessive exercise, obligatory exercise, exercise dependence), key commonalities are that this group of individuals is characterized by low self-esteem, they use exercise as a control mechanism for managing and/or manipulating psychological states, though they are controlled by the activity, display increased body dissatisfaction, and are vulnerable to serious and long-lasting injuries related to overtraining (e.g., Ackard, Brehm, & Steffen, 2002; Cockerill & Riddington, 1996; Slay, Hayaki, Napolitano, & Brownell, 1998; Symons Downs, Hausenblas, & Nigg, 2004). For the purpose of this research, we use the term exercise addiction.

Given the research suggesting that exercise may become an addiction for some individuals, De Coverley Veale (1987) proposed diagnostic criteria for exercise dependence associated with the addiction. These criteria included: (a) a stereotyped pattern of exercise once or more daily; (b) priority for exercise over other activities; (c) increased tolerance to exercise; (d) withdrawal symptoms including mood changes; (e) avoidance of withdrawal symptoms by further exercise; (f) subjective awareness of a compulsion to exercise; and (g) rapid reinstatement of excessive exercise after a period of abstinence. In addition, De Coverley Veale distinguished between primary and secondary exercise dependence. Primary exercise dependence is when an individual who does not have an associated eating disorder adapts to life through exercise, and he or she cannot function effectively when prevented from exercising (see Cockerill & Riddington, 1996). This is the type of dependence/addiction examined in the current study.

Secondary exercise dependence, on the other hand, involves the presence of an eating disorder, exercise being used as a means of losing weight or controlling body shape and size. The exercise reaches a stage of dependence, but it is still regarded as secondary to the eating disorder.

The question that remains is why some individuals become dependent on exercise while others may engage in similar amounts of activity without any pathological consequences. It is important to obtain a greater understanding of this form of exercise behavior because of its numerous deleterious effects (e.g., risk of overtraining injuries, negative affect when unable to exercise, prioritizing exercise ahead of other responsibilities). One theory proposed to explain exercise addiction as it relates to emotion is the affect regulation hypothesis (Tomkins, 1968), proposes

that individuals exercise for one of two reasons: either to reduce negative affect or to increase positive affect. Exercise addicts would most likely fit into the former as they seek exercise as a relief from stress and discomfort (Cockerill & Riddington, 1996). Research to support the notion of exercise addiction as related to negative affect comes from studies examining the effects of exercise deprivation and/or withdrawal in chronic exercisers. Collectively, the literature shows that when deprived of, or asked to withdraw from, exercise participation, participants report increased tension, anxiety, distress, irritability, frustration, guilt, and depression (Baekeland, 1970; Chan & Grossman, 1988; Conboy, 1994; Crossman, Jamieson, & Henderson, 1987; Morris, Steinberg, Sykes, & Salmon, 1990; Robbins & Joseph, 1985; Szabo, Frenkl, & Caputo, 1997; Thaxton, 1982). Based on these findings, individuals may become addicted to exercise because they seek to maintain the psychological benefits they experience inasmuch as the exercise staves off these negative emotions.

For any consideration of the affect regulation hypothesis, it is valuable to examine the similarities between drug addiction and exercise addiction in terms of affect regulation. Asymmetric frontal brain activity has been identified as a potential common mechanism because of its association with negative affect (Beh, Mathers, & Holden, 1996; Pargman & Baker, 1980; Wagemaker & Goldstein, 1980). The prefrontal cortex has been proposed as the central structure involved in emotional response patterns, which are organized primarily into either the approach or withdrawal system. These two systems are reflected by lateralized activity patterns in the prefrontal cortex. A common, although not universal, finding across studies is the relatively greater activity at right frontal electrode sites among individuals suffering from negative affect and depression (Abercrombie et al., 1998; Kentgen et al., 2000; Miller, Fujioka, Chapman, & Chapman, 1995). Additionally, this pattern of asymmetry is tied to a predisposition to be more sensitive to threatening stimuli, a heightened experience of withdrawal-related emotions, and a decreased ability to voluntarily regulate negative affect (see Davidson, 1992, for a review). The hypothesis that positive affect is associated with greater relative left activity and negative affect is associated with greater relative right activity has been referred to as the affective-valence hypothesis of EEG frontal asymmetry. For the exercise addict, life is organized around exercise, possibly to fulfill a need for self-regulation and to control negative affect – in other words, to defend against experiencing anticipated stressful emotions. In the long term, the fundamental etiological factors of emotional distress are not dealt with, and the individual becomes dependent on exercise to manage affective states.

To date, studies have primarily examined the *psychophysiological* mechanisms behind addictive behaviors related to alcohol and drug use; yet this paradigm has not been applied to the study of exercise addiction. Previous research on the causes of exercise addiction has focused primarily on the role of personality traits, social influences, and disordered eating (Bamber, Cockerill, & Carroll, 2000; Beals, 2004). However, there is a clear gap in the literature because there are few studies in the psychophysiology literature examining the role of EEG in exercise-addicted individuals. And only one study (Beh et al., 1996) examined the relationship between EEG activity (an indicator of brain activity) and exercise addiction. In this study researchers found that the power distributions within the alpha band were different for exercise-addicted individuals compared to nonaddicted participants, which is indicative of chronic differences in cortical arousal. However, results from this study are somewhat limited in that the dependency measure is outdated. Research considering the connection between psychophysiology and

exercise addiction specifically is rather limited. Therefore, the objective of this study was to further explore the hypothesized relationship between exercise addiction and the level of baseline frontal activity asymmetry, as measured by EEG. In this way, it is possible to test the prediction that exercise addicts are characterized by relatively greater right frontal activity (indicative of greater negative affect) than are regular exercisers who are not addicted to exercise.

Methods

Participants

Participants were recruited via flyers from the university and surrounding community. The flyers called for women who were regularly physically active and who would be interested in participating in a study related to exercise and brain activity.

A total of 28 women, M age = 32.43, SD = 10.89, all of whom were regularly physically active, participated in the study. The majority of the participants were Caucasian (93%, n = 26) and the remainder of the sample was African-American (7%, n = 2). All participants were right-handed based on self-report.

Measures

Exercise Addiction Inventory (EAI, Terry et al., 2004)

The EAI was chosen because it is the only theory-based scale that assesses exercise addiction. It was also selected because other conceptually similar scales take a long time to administer, are more complicated to score, and are difficult to use as screening tools. The EAI is based on Griffiths' (1996) six behavioral components of addiction: salience, mood modification, tolerance, withdrawal symptoms, conflict, and relapse. The inventory consists of six statements in 5-point Likert-style format. The statements are coded so that high scores are indicative of exercise addiction: 1 = *strongly disagree*, 2 = *disagree*, 3 = *neither agree nor disagree*, 4 = *agree*, 5 = *strongly Agree*. The six statements are:

1. Exercise is the most important thing in my life.
2. Conflicts have arisen between me and my family and/or my partner about the amount of exercise I do.
3. I use exercise as a way of changing my mood.
4. Over time I have increased the amount of exercise I do in a day.
5. If I have to miss an exercise session I feel moody and irritable.
6. If I cut down on the amount of exercise I do, and then start again, I always end up exercising as often as I did before.

This self-report measure has very good internal consistency (r = .84) and exhibits excellent concurrent validity when compared to the Obligatory Exercise Questionnaire (r = .80) (Thompson & Pasman, 1991) and the Exercise Dependence Scale (r = -.81) (Hausenblas & Symons Downs, 2002).

Questionnaire for Eating Disorder Diagnoses (Q-EDD) (Mintz, O'Halloran, Mulholland, & Schneider, 1997)

The Q-EDD is a self-report instrument designed to assess eating disorder symptomology according to DSM-IV criteria. Scores on the Q-EDD are able to differentiate between clinical eating disorders, subthreshold eating disorders, and noneating disorders. Adequate reliability and validity were found when using the Q-EDD (Mintz et al., 1997). Also, the Q-EDD has been shown to have a sensitivity of 97% and a specificity of 98% compared to the use of DSM-IV criteria in an interview format (Mintz et al., 1997). The Q-EDD was included to ensure that participants were not suffering from an eating disorder at the time of the study and to rule out participants who may have secondary exercise dependence (i.e., their exercise dependence is a result and/or symptom of their eating disorder, see above). For the purpose of this study, we wanted to limit our sample to individuals with primary exercise dependence (i.e., exercise dependence in the absence of an eating disorder, see above). Previous research on exercise addiction often neglected obtaining information about eating disorders, thus making an interpretation of exercise behavior itself more difficult.

Godin Leisure-Time Physical Activity Questionnaire (Godin & Shephard, 1985)

This questionnaire was used to assess leisure-time physical activity levels in the sample of participants. Participants were asked to indicate how many times per week they engage in strenuous, moderate, and mild exercise. Weekly frequencies for the strenuous, moderate, and mild activity categories are multiplied by nine, five, and three respectively for a conversion into energy expenditure units called metabolic equivalents (METs). A total weekly leisure activity score is obtained from the sum of these three MET values. This questionnaire has good test-retest reliability for measures of total leisure activity ($r = .74$) and for the frequency of strenuous ($r = .94$), moderate ($r = .46$), and light ($r = .48$) activity (Godin & Shepard, 1985).

Procedure

All participants were instructed not to engage in exercise or have caffeine within 4 h of the testing time in order to avoid confounding effects. After arriving at the laboratory, the subject read and signed a consent form that was approved by the University's Institutional Review Board. The electrodes were then applied, and the subject was asked to relax. The EEG session included eight 1-min resting trials of EEG, four with eyes open (O), and four with eyes closed (C), presented in one of two counterbalanced orders assigned (either O-C-O-C-C-O-C-O or O-O-C-C-O-C-C-O). These sequences stemmed from previous EEG studies (e.g., Gotlib, Ranganath, & Rosenfeld, 1998). Participants were instructed to open or close their eyes prior to each of the eight trials and were required to give the researcher a hand signal when they were ready for each 1-min trial to begin. To avoid any emotional distress that might be caused by answering the questions on the survey, participants filled out the questionnaires following completion of the EEG session. Questionnaires were scored following the EEG sessions, so the experimenters were not aware of EAI scores during data collection or data reduction phases.

EEG Recording, Quantification, and Analysis

A 32-channel NeuroScan EEG and Evoked Response Workstation (Compumedics, Charlotte, NC, USA), with SCAN 4.0 software, was used to acquire the EEG data. An electrode cap (Electrocap International, Eaton, OH, USA) was used to place silver-silver chloride electrodes over the left and right frontal sites (F3 and F4) as specified by the 10–20 International sites (Jasper, 1958). Data was collected from the F3 and F4 channels because prior research had indicated that the sites F3 and F4 are reliably related to negative and positive affect and emotion states (Sutton & Davidson, 1997). The electrodes were linked to the right and left mastoids as reference sites so that an offline averaged ears' reference could be obtained.

Eye movement (electrooculogram, EOG) was recorded from electrodes placed above and below the subject's left eye to allow for the removal of artifacts from the EEG. Another electrode, placed at the middle of the forehead served as the ground. The EOG sites were all cleaned with isopropyl alcohol before electrode application. Electrode gel was applied to the specified sites to produce conductivity for obtaining the scalp measures of EEG activity. All impedances were maintained below 5,000 Ω with minimal impedance differences between the left and right electrodes. Impedance values for homologous sites were within 1,000 Ω of each other. EEG scalp electrical activity was amplified and filtered with digital filters. The high- and low-bandpass filters for the EEG measures were set at .01 and 100 Hz, respectively, and the signals were amplified 50,000 times. The high and low bandpass filters for the EOG measures were set at .01 Hz and 100 Hz, respectively, and the signals were amplified 10,000 times. The sampling rate for all signals was 256 Hz.

All artifacts (eye blinks) were visually inspected and manually rejected based on guidelines in the Neuroscan manual. Only artifact-free data was extracted and used in the EEG analysis. A fast fourier transform (FFT) was used to obtain the power spectrum data, and all power values were then averaged over the eight trials. Total power within the alpha band was obtained (8–12 Hz) and all values were log transformed in order to normalize the data. Alpha power was used because it has been shown to be a sensitive discriminator of arousal (e.g., Davidson, 2004; Gale & Edwards, 1983).

All asymmetry indexes were computed using a natural log transformation to normalize the data, and log left values were subtracted from log right values (log F4–F3; Henriques & Davidson, 1991). Since alpha power is inversely related to brain activity, positive asymmetry scores represent relatively greater alpha (less activity) over right than left hemispheres (Coan & Allen, 2004).

Results

A total of 28 women participated in the study. Self-reported descriptive information (i.e., age, height, weight) relative to the total sample is presented in Table 1. To describe the physical make-up of the sample of women, we calculated Body Mass Index (BMI = weight in kilograms divided by height in meters squared) for each participant based on the self-reported height and weight (see Table 1). Results from the Q-EDD revealed that none of the participants had a clinical eating disorder.

Table 1. Means, standard deviations, and ranges for descriptive information, Exercise Addiction Inventory (EAI), physical activity variables, and EEG data

	<i>M</i>	<i>SD</i>	Range
Age	32.43	10.89	19–61
Height (in)	64.55	2.98	59–70
Weight (lbs)	138.41	22.78	99–198
BMI	23.37	3.76	19.33–33.98
EAI Total	20.79	3.57	16–28
Total METS	56.62	19.03	14–94
Strenuous (METS)	37.24	19.61	0–72
Moderate (METS)	11.98	10.05	0–35
Mild (METS)	8.48	7.52	0–21
F4 log	3.23	0.74	1.80–4.81
F3 log	3.15	0.72	1.66–4.64
Log F4-Log F3	0.08	0.16	–0.29–0.32

Note. EEG = electroencephalogram.

When interpreting scores on the EAI, a cutoff score of 24 determines individuals who are “at risk” for exercise addiction and represents individuals in the top 15% of the total scale score. A score in the range of 13–23 indicates that individuals are symptomatic, and a score of 0–12 would mean an individual is asymptomatic (Terry et al., 2004). EAI scores are presented in Table 1. In this sample of women, nine participants scored above the EAI cut off score of 24 and were identified as exercise addicts ($M = 25.50$, $SD = 1.69$), whereas the remaining women ($n = 19$) scored between 13–23 and were identified as symptomatic ($M = 18.90$, $SD = 1.99$).

Physical Activity

When examining exercise frequency over a 7-day period, participants reported engaging in an average of four bouts of strenuous exercise, two bouts of moderate exercise, and three bouts of mild exercise. MET values for these exercise bouts as well as the Total METs are presented in Table 1. A regression analysis, predicting exercise addiction from total MET values was significant, $F(1, 27) = 5.73$, $p < .05$. A correlation matrix for all variables (physical activity, EAI, and EEG) is included in Table 2 .

Table 2. Correlation matrix for the exercise addiction, EEG, and physical activity measures

Measure	1	2	3	4	5
1. EAI	—				
2. Log F4-F3	.44*	—			
3. Total METS	.43*	.19	—		
4. METS Mild	.08	.20	.39*	—	
5. METS Moderate	.23	.34	.36*	.53	—
6. METS Strenuous	.27	–.08	.66**	–.30	–.38

Note. EAI = Exercise Addiction Inventory. * $p < .05$, ** $p < .01$.

EEG

EEG data, including descriptive information for F3, F4, and Log F4-F3, are displayed in Table 1. A regression analysis, predicting exercise addiction from EEG asymmetry, was significant, $F(1, 27) = 6.4$, $p < .05$. As evident in Figure 1 , this regression analysis indicated that the asymmetry

index also increases as one's exercise addiction score increases, indicating that higher exercise addiction scores are predictive of greater relative left frontal activity (less alpha activity), with 19.8% of the variance accounted for by asymmetry scores ($\beta = .44, p < .05$). This relationship remained significant ($\beta = .43, p < .05$) after controlling for potential covariates (age, BMI, physical activity levels, and race).

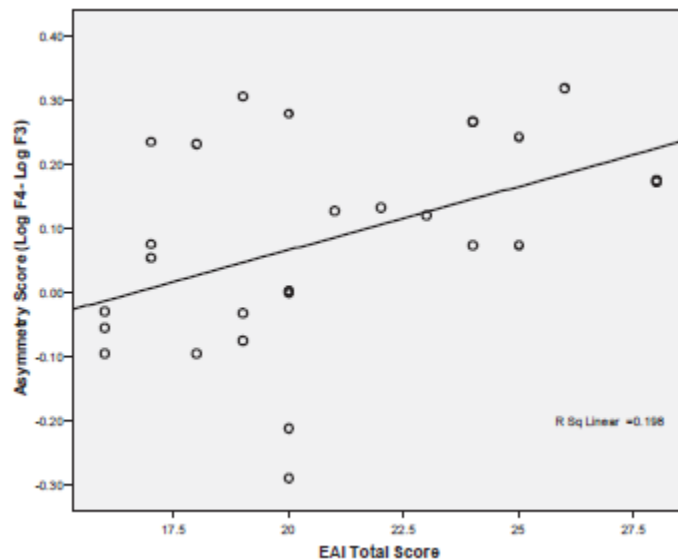


Figure 1. Scatterplot displaying the relationship between frontal asymmetry and scores on the Exercise Addiction Inventory (EAI). Higher (more positive) asymmetry scores reflect higher left relative to right activity.

Discussion

This study examines the relationship between frontal brain asymmetry and exercise addiction in a sample of regularly active women. In the light of the past literature with both exercise addiction and frontal brain asymmetry, we hypothesized that exercise addicts would display greater right frontal activity, indicative of more negative affect. Contrary to our prediction, these results did not show that exercise addicts are characterized by greater relative right frontal activity. Instead, the results showed that greater exercise addiction was predictive of greater left frontal activity. There are a few possible explanations for why the relationship was not in the hypothesized direction. First, it is plausible that exercise addiction (and potentially other forms of addiction as well) are “fueled” by negative affect, resulting in EEG asymmetry with right activity relatively greater than left, but that in this sample exercise served as an effective coping mechanism. In other words, the maintenance of an exercise regime may enable the addiction and, thus, contributes to the continuation of the addict’s positive affect. If the addict is using exercise to cope with negative mood states and is able to exercise, then the exercise is “working” as it were to combat negative affect, so that asymmetry should reflect positive, rather than negative, affect. In this sense a positive feedback loop is created in which the individual learns to manipulate her feeling states with exercise. Exercise becomes more and more salient as the individual realizes the importance of the activity for achieving pleasant affect. Taken as a whole, the engagement in exercise would *decrease* the presence and/or severity of negative affect and therefore *increase* relative activation of the left frontal cortex.

If we consider the affect regulation hypothesis, we can see how this hypothesis may explain the finding of increased activity in the left hemisphere for this sample of regular exercisers. Research in support of the affect regulation hypothesis is evident in studies demonstrating that reducing stress, anxiety, and depression are the primary motives for exercise behavior in exercise addicts versus nonaddicts (Anshel, 1991; Johnsguard, 1985). Additionally, Anshel (1991) found in their sample of exercise addicts that they were more anxious, restless, and stressed prior to engaging in a workout compared to nonaddicts. The addicts also experienced greater increases in positive affect following exercise. Similar results for these positive effects of exercise on mood were found in a sample of exercise addicted individuals who completed mood state measures before and after engaging in maximal exercise (Rosa, De Mello, Negrao, & De Souza-Formigoni, 2004). This point may be particularly relevant to the methodology used in the study since we allowed participants to exercise on the testing day, only requiring that they not exercise within the 4 h prior to the EEG test. Thus, although we do not have data to confirm or deny this possible explanation, given their predilection to exercise, it is certainly likely that participants either exercised earlier in the day and were experiencing positive affect as a result of that exercise or were experiencing positive affect in anticipation of an exercise bout to be performed following the EEG session.

A second explanation for the results is that, while this study approached the research question using the affective regulation hypothesis, there exists a competing theoretical framework to explain EEG frontal asymmetry. This framework, referred to as the motivational directional hypothesis, posits that greater relative left activity is associated with approach motivation, whereas greater relative right activity is associated with withdrawal motivation. A large number of studies support this view, specifically for the emotions of anger and aggression (Davidson, 1992; Harmon-Jones, 2004; Peterson, Shackman & Harmon-Jones, 2008; Schiff, Guirguis, Kenwood, & Herman, 1998). Anger and aggression are both negative emotions that elicit approach motivation. From this perspective, individuals addicted to exercise may be characterized by greater relative left activity because they are more likely to engage in behaviors (i.e., approach exercise) that they know will enable them to cope with stressful demands. In this case, approach motivation may actually result in negative consequences (physical and psychological) as the individual continuously seeks out exercise – even at the expense of other life activities – to reduce the possibility of negative emotions and events occurring (Harmon-Jones, 2003).

In addition to the results related to frontal asymmetry, there were a few other notable findings related to physical activity levels in this sample of women. One is that the total amount of exercise individuals participated in (total METS) was a significant predictor of exercise addiction scores. This demonstrates that individuals who scored higher on the EAI engage in exercise more frequently and/or for longer amounts of time than those that score lower on this scale. This contradicts the findings of others using varied forms of exercise (e.g., Ackard et al., 2002; Hulley & Hill, 2001; Steffen & Brehm, 1999), which show that the volume of exercise did not vary significantly among persons addicted to or dependent on exercise and among those who were not. Further, the results of this study, although nonsignificant, demonstrated that individuals who displayed higher exercise-addiction scores also self-reported (i.e., perceived) more bouts of strenuous exercise (as opposed to mild or moderate exercise). This suggests that it may not be

the volume of exercise that is important, but the *perceived intensity* of the exercise that brings about the desired changes in affect for the individual.

It is also important to note that, among those addicted to exercise, none had a clinical eating disorder, suggesting that exercise behavior of these individuals is not driven by characteristics of an eating disorder. One of the primary weaknesses in the extant exercise addiction literature is the lack of assessment of eating disorder status when examining exercise behavior. As mentioned previously, individuals with primary vs. secondary exercise addiction may have different motives and be characterized by different psychophysiological patterns. Therefore, having a sample of exercise addicts and symptomatic individuals who do not have an eating disorder is a fundamental strength of this study.

Based on the results of this study, future research would benefit from including a subjective measure of affect to measure current mood states. It would also be important to include a measure of approach withdrawal behavior, such as the Behavioral Approach Sensitivity (BAS) scale (Carver & White, 1994) to help distinguish between the affective regulation hypothesis and the motivational direction hypothesis. In addition, it would be of benefit to attain measures of EEG activity in exercise addicts and symptomatics on a day when they are not exercising to see if this impacts the nature of the findings. However, because of the nature of exercise addiction, it will be difficult to obtain a sample of true exercise addicts who will abstain from participating in exercise for a research study. Also, it may be helpful to look at activity across the entire scalp by obtaining measurements using the full 32- or 64-channel recordings. Finally, future studies using larger sample sizes will be needed to confirm the reliability of these findings.

From a practical perspective, understanding the relationship between brain mechanisms and exercise behavior is valuable in learning how to treat individuals who suffer psychologically and physically from excessive exercise. Exercise addiction has been associated with high injury rates such as joint and tissue damage, stress fractures, depressed immune system functioning, inability to concentrate, lapses in judgment, constant thoughts about exercise, and impaired social and work activity (Chapman & DeCastro, 1990). It is apparent from these negative consequences that research is needed to examine all possible variables – not just social or psychological – that contribute to the development of exercise addiction.

Overall, this study demonstrated that exercise addicts display frontal asymmetry that is consistent with more positive affect. While causal relationships between EEG data and exercise addiction are unclear and remain speculative, they are well grounded in theory. This evidence in support of examining the psychophysiological nature of exercise addiction is important and will hopefully provide the impetus for more research in this area.

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